Assessing reliability and validity of different stiffness measurement tools on a multi-layered phantom tissue model

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Abstract

Changes in the mechanical properties (i.e., stiffness) of soft tissues have been linked to musculoskeletal disorders, pain conditions, and cancer biology, leading to a rising demand for diagnostic methods. Despite the general availability of different stiffness measurement tools, it is unclear as to which are best suited for different tissue types and the related measurement depths. The study aimed to compare different stiffness measurement tools' (SMT) reliability on a multi-layered phantom tissue model (MPTM). A polyurethane MPTM simulated the four layers of the thoracolumbar region: cutis (CUT), subcutaneous connective tissue (SCT), fascia profunda (FPR), and erector spinae (ERS), with varying stiffness parameters. Evaluated stiffness measurement tools included Shore Durometer, Semi-Electronic Tissue Compliance Meter (STCM), IndentoPRO, MyotonPRO, and ultrasound imaging. Measurements were made by two independent, blinded examiners. Shore Durometer, STCM, IndentoPRO, and MyotonPRO reliably detected stiffness changes in three of the four MPTM layers, but not in the thin (1 mm thick) layer simulating FPR. With ultrasound imaging, only stiffness changes in layers thicker than 3 mm could be measured reliably. Significant correlations ranging from 0.70 to 0.98 (all $p < 0.01$) were found. The interrater reliability ranged from good to excellent (ICC(2,2) = 0.75-0.98). The results are encouraging for researchers and clinical practitioners as the investigated stiffness measurement tools are easy-to-use and comparatively affordable.